Exhibit 2 to Statement of Undisputed Facts Filed in Support of Motion of Hardric Laboratories, Inc. For Summary Judgment

RICHARD DEPOSITION EXCERPTS

PART TWO

FILED UNDER SEAL

MAY 22 2006

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EXHIBIT
PENGAD 800-631-6989
Richards 2
5-25-06

Re. Genereux, et al. v. American Beryllia Corp., et al., United States District Court for the District of Massachusetts, Case No. 04-CV-12137 JLT

Dear Counsel:

Pursuant to my telephone conversation with Rubin and Stephan this afternoon, I am at long last producing everything found at Hardric relevant to this case. Unfortunately, there is very little. As I explained to Plaintiffs' counsel, Hardric disposed of all its documents, including invoices and correspondence, from prior to 1999 after a flood and before moving to its current location. The enclosed warning labels are not from the relevant time period, but are thought be similar to what was used then, as Peter Richards can explain at more length in his deposition.

I look forward to hearing from you with questions and to seeing you next week at our deposition marathon.

Very truly yours,

Frances C. Lindemann

FCL/jmp
Enclosure
cc: Peter Richards

20994 RAYTHEON / ElSegundo 1 Pc.
Hardric Laboratories, Inc. S/N 10006
No. Chelmsford, MA 01863 U.S.A
4U884-6539853 (B)
WARNING MFR 3S571 BERYLLIUM

20994 RAYTHEON / ElSegundo 1 Pc.
Hardric Laboratories, Inc. S/N 10007
No. Chelmsford, MA 01863 U.S.A
4U884-6539853 (B)
WARNING MFR 3S571 BERYLLIUM

20994 RAYTHEON / ElSegundo 1 Pc.
Hardric Laboratories, Inc. S/N 10008
No. Chelmsford, MA 01863 U.S.A
4U884-6539853 (B)
WARNING MFR 3S571 BERYLLIUM

20994 RAYTHEON / ElSegundo 1 Pc.
Hardric Laboratories, Inc. S/N 10005
No. Chelmsford, MA 01863 U.S.A
4U884-6539853 (B)
WARNING MFR 3S571 BERYLLIUM

20994 RAYTHEON / ElSegundo 1 Pc.
Hardric Laboratories, Inc. S/N 10005
No. Chelmsford, MA 01863 U.S.A
4U884-6539853 (B)
WARNING MFR 3S571 BERYLLIUM

SAMPLE THAT GOES ON BOX WITH PRODUCT

JOB #
Ser. #
PROD #

Customer

SAMPLES

WARNING
BERYLLIUM
Hazardous Dust Produced When Machined, Filed or Ground.
HANDLE WITH CARE

WARNING
BERYLLIUM
Hazardous Dust Produced When Machined, Filed or Ground.
HANDLE WITH CARE

WARNING
BERYLLIUM
Hazardous Dust Produced When Machined, Filed or Ground.
HANDLE WITH CARE

WARNING
BERYLLIUM
Hazardous Dust Produced When Machined, Filed or Ground.
HANDLE WITH CARE

M10
1/13/03

Beryllium Solid

WARNING

INHALING DUST OR FUMES MAY CAUSE CHRONIC BERYLLIUM DISEASE, A SERIOUS CHRONIC LUNG DISEASE, IN SOME INDIVIDUALS. CANCER HAZARD. OVER TIME, LUNG DISEASE AND CANCER CAN BE FATAL. TARGET ORGAN IS PRIMARILY THE LUNG.

READ THE MATERIAL SAFETY DATA SHEET (MSDS) ON FILE WITH YOUR EMPLOYER BEFORE WORKING WITH THIS MATERIAL.

Overexposure to beryllium by inhalation may cause chronic beryllium disease, a serious chronic lung disease.

- If processing or recycling produces airborne dust, fumes, or mists, use exhaust ventilation or other controls designed to prevent exposure to workers. Examples of such activities include melting, machining, welding, grinding, abrasive sawing, sanding and polishing. Any activity which abrades the surface of this material can generate airborne dust.
- The Occupational Safety and Health Administration (OSHA) has set mandatory limits on occupational exposure;
- Beryllium metal, in solid form and as contained in finished products presents no special health risks.
- Sold for manufacturing purposes only. This product can be recycled; contact your sales representative.

The Occupational Safety and Health Administration requires employers to provide training in the proper use of this product.

[illegible]

M1[illegible]

Beryllium Mirrors:
Refinements Enable New Applications

Vladimir Vudler and Peter Richard
Hardric Laboratories, Inc.

Beryllium mirrors are finding commercial applications, while maintaining their military and space applications. Refinements in design and improvements in manufacturing technology have cut costs and new coatings have enabled high-power applications allowing a three-fold increase in manufacturing process speeds and economics.

With a specific gravity of 1.85 g/cm³, beryllium is the lightest metal that is workable. It is 45 percent lighter than aluminum and approximately five times as stiff. Its stiffness to weight ratio (164) makes it a natural for low inertia, fast scanning applications. Since the 1980s, beryllium mirrors have been used in semiconductor manufacturing and memory repair; beryllium's light weight assures speed and its stiffness assures accuracy of figure to the optics.

Many applications benefit from beryllium's natural heat sink and radiator qualities. Its excellent thermal conductivity (216 W/mK), thermal capacity (specific heat 1925 J/kg K), and emissivity of 0.61 at 650 nm as well as its natural 98+ percent reflectivity in the IR at 10.6 µm and above (Figure 1) enable very high processing speeds in CO_2 laser applications for material processing where the optics must handle high heat loads while maintaining optical integrity and ensuring machine uptime. With enhanced coatings, such as Hardric's HardZap coating for CO_2, YAG and UV lasers, manufacturing speeds are even faster.

The beryllium mirror surface is rugged and has been used as scanning mirrors (flat, monogon and polygon), folding mirrors and camera shutters where light weight, portability and ruggedness are important in space, military and medical applications (Figure 2). The polished beryllium surface is a very durable thin coating of ceramic. Optical coatings on this polished surface are similarly durable. The mirrors can be stabilized over a wide range of temperatures (4 to 500 K) and have exhibited substantial long-term dimensional stability as well as stability of the optic surface (longer than 10 years in some ap-

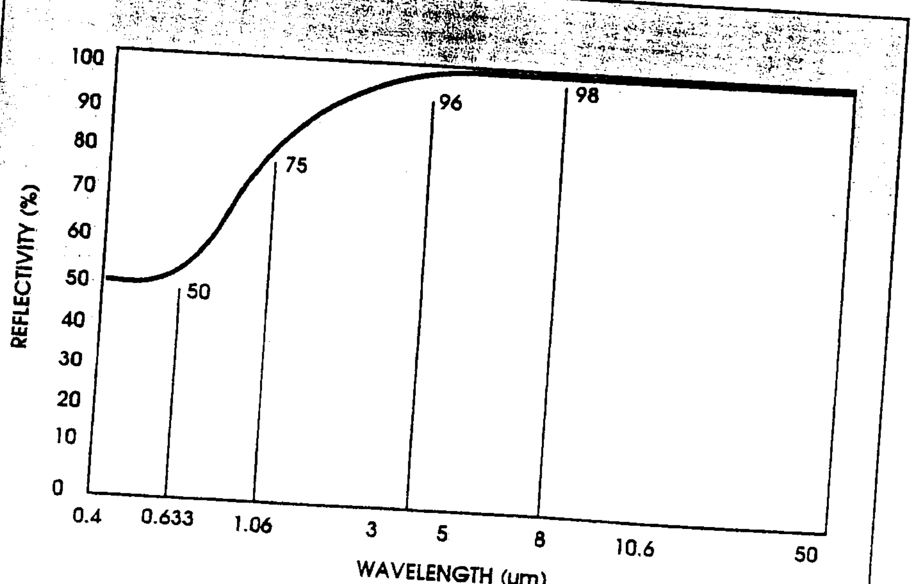


Figure 1. Reflectance curve for bare, polished beryllium surfaces. There are no known anomalies in the progression of reflectivity for beryllium from 0.4 through 50 µm. The reflectance curve above is valid for S-200-F and I-220-H beryllium grades. Slightly higher reflectivity is usual for I-70-H beryllium.

TABLE 1.
PHYSICAL PROPERTIES OF SELECTED OPTICAL MATERIALS

	BERYLLIUM I-70-H	BERYLLIUM S-200-F	BERYLLIUM I-220-H	ALBEMET AM 162	BERYLCAST 363	ALUMINUM 606IT-6	QUARTZ
Inertia Ratio	1	1	1	1.12	1.17	1.46	1.19
Density G/cm³ (lb/in.³)	1.85 (0.067)	1.85 (0.067)	1.85 (0.067)	2.071 (0.075)	2.16 (0.078)	2.70 (0.098)	2.202 (0.0795)
Modulus of Elasticity Gpa (Msi)	303 (44)	303 (44)	303 (44)	193 (23)	202 (30)	69 (10)	74.5 (10.8)
Modulus of Elasticity vs. Density	164	164	164	93	94	26	34
Poisson Ratio	0.12	0.18	0.12	0.17	0.2	0.33	0.16
Thermal Conductivity Btu/in.-h °F (W/m-h K)	1499 (216)	1501 (216)	1499 (216)	1457 (210)	732 (106)	1186 (171)	0.2 (1.36)
Specific Heat Btu/lb °F (J/kg K)	0.46 (1925)	0.46 (1925)	0.46 (1925)	0.37 (1560)	0.30 (1250)	0.23 (962)	0.177 (741)
Coefficient of Thermal Expansion µin./in. °F (µm/m-K)	6.3 (11.4)	6.3 (11.4)	6.4 (11.5)	7.7 (13.91)	7.6 (13.7)	13.2 (23.8)	0.30 (0.54)

plications for laser engraving, IR cameras and space instruments), thus accommodating a variety of applications. Also, the bare beryllium surface can be easily cleaned with a tissue and acetone.

Design considerations

When designing a beryllium mirror, it is important to understand how the requirements of an application affect the design of the mirror.

Material choices — Brush Wellman, Inc. is the primary supplier for beryllium used in optics. Beryllium is mined from high-grade beryl ore and bertrandite and manufactured into shapes using powder metallurgy techniques. Three grades of Brush Wellman material are generally used for optics: I-70-H (optical grade), I-220-H and S-200-F (Table 1).

Aluminum-beryllium is a metal-matrix composite that was developed as a low-cost alternative to beryllium. Its characteristics lie between those of the two metals. Unlike beryllium, it cannot be directly polished and must be plated in order to have a surface that can be polished or diamond turned. Aluminum-beryllium composites are supplied by two companies: Brush Wellman, supplier of AlBeMet and Starmet, Inc., supplier of Berylcast (Table 1). The cost-effectiveness of an aluminum-beryllium mirror *vis a vis* beryllium depends on the size and complexity of the mirror, and whether plating could generate bimetallic problems.

Manufacturing process

Mirror blank — Most pure beryllium mirror blanks are machined using conventional CNC fabricating equipment. For the very largest mirrors made of pure beryllium, it may be more cost effective to use near net shaping which was developed by Brush Wellman as a cost-effective method of manufacturing large mirror blanks and structures.

Aluminum-beryllium can be either machined or cast in order to make the mirror blank. Starmet developed the casting process for its Berylcast material in order to manufacture large, lightweight structures and frames. Berylcast mirrors are currently used in aerospace applications; the mirror blanks range in size from 4 in. (10 cm) diameter to 10 in. (25.4 cm) oblong.

Size and shape of mirror — Beryllium mirrors have been made

TABLE 2.
POWER HANDLING OF HIGH-POWER BERYLLIUM MIRRORS

	CO_2	YAG	UV
Wavelength	10.6 μm	1.064 μm	355 nm
Reflectivity	99+ %	99+ %	98+ %
CW/Quasi CW Power Damage Threshold	Not reached	Not reached	22.2 MW/cm², 90 ns pulse
Operating Power	1+ MW/cm²	100+ kW/cm²	4 kW/cm² at 2 kHz
Pulsed Power Damage Threshold	7.9 J/cm², 120 ns pulse	4.9 J/cm², 15 ns pulse	6.6 J/cm², 7 ns pulse

HardZap mirrors measured at 45° angle of incidence.

in sizes ranging from smaller than 1/4 in. (5 mm) to greater then 40 in. (1 m) in diameter and in many different shapes, though most commercial mirrors range from 1/4 in. (5 mm) to 12 in. (30.5 cm) in diameter. A major difference between beryllium mirrors and mirrors made of other materials lies in the thickness of the mirror. Beryllium mirrors can be made very thin with ribs or pockets on the back side for rigidity. For example, Hardric manufactured 4 in. (10 cm) × 3 in. (7.6 cm) mirrors with a face 0.02 in. (1/2 mm) thick and ribs of 0.02 in. (1/2 mm).

Mount and mass balancing — Some beryllium mirrors are manufactured with mounts integral with the mirror, thus avoiding an increase in inertia which occurs when heavier materials are used for the mount. Shafts also can be integral with the mirror; however, for most applications steel shafts are adequate.

Additionally, mirrors with integrated mounts can be manufactured as mass balanced. Mass balancing is important for scanning mirrors because it optimizes the dynamic positioning of the beam and minimizes vibration of the mirror. Where nonintegrated designs require the use of epoxies in the balancing process, integrated designs are void of the epoxy and its heat barrier. The integrated, all-beryllium, mass-balanced mirror maximizes heat dissipation, making it an excellent mirror for high-power infrared laser applications.

Anticorrosion techniques — Corrosion of the beryllium mirror can be caused by water, acidic or other harsh environments. To prevent corrosion, the mirror can be protected with any of the following, the choice being determined by the application: irridite, anodize, Teflon, nickel or gold.

Beryllium matching — Because beryllium is an expensive material, it is not often cost effective to make a complete mirror and optical housing of beryllium. There are several less expensive materials with simi-

Figure 2. *Beryllium mirrors. The camera shutter is 12 in. point-to-point. The smaller mirrors demonstrate a variety of mirror shapes as well as rib structures, mounts, shafts and back side mirrors used for alignment or registration.*

Manufacture of mirror surface — Tolerances on an optical figure are a cost driver. It is possible to polish a bare beryllium mirror to a surface finish of 10 Å rms or better, and a 50 Å diamond-turned electroless nickel surface can be post-polished to a 5 Å rms or better surface finish. However, it takes longer (higher cost) to make a perfect surface and nickel coating adds cost, weight and potential bimetallic problems.

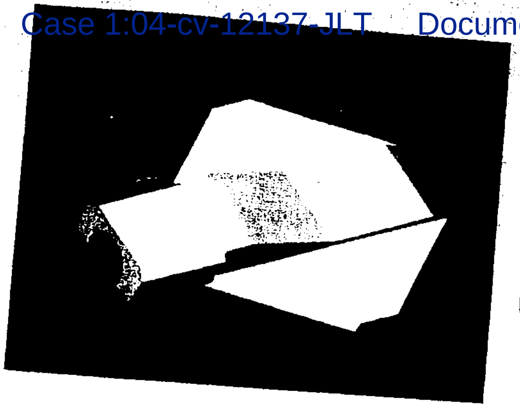
For practical applications, a surface finish of 20 Å is a reasonable working limit for bare beryllium optics. A surface flatness of 1/20 wave and better also can be achieved on a bare beryllium mirror. It is easier to achieve the more exacting surface finishes on smaller mirrors.

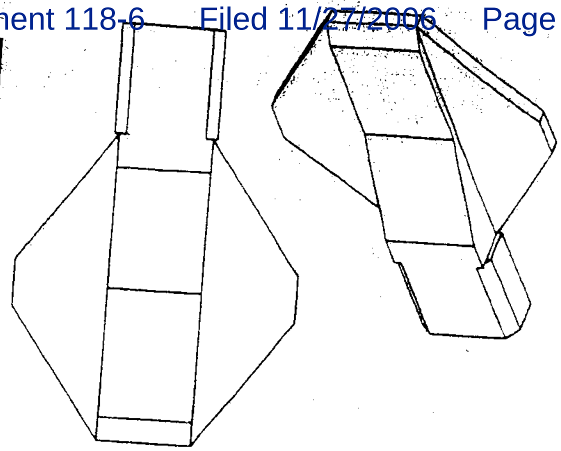
Special coatings — Special coatings are not required for all applications. For applications with lower power requirements at 10.6 μm, an uncoated bare beryllium mirror is probably adequate and would be the least expensive beryllium mirror. Many IR camera mirrors also do not need coatings.

Applications

The first applications for beryllium mirrors were night-vision systems and space cameras for the military. Today, they are used also in other high-resolution cameras such as those for terrestrial mapping. Additionally, beryllium mirrors have vastly improved efficiencies of laser cutting machines for various materials and have enabled very high power handling for welding, drilling and cutting applications. These high-power laser mirrors are bare beryllium with proprietary coatings designed for handling the high-power loads, and they run uncooled. □

HardZap is a trademark of Hardric Laboratories. The following are registered trademarks: AlBeMet of Brush Wellman, Berylcast of Starmet and Teflon of DuPont.





For a competitive edge, your system needs:

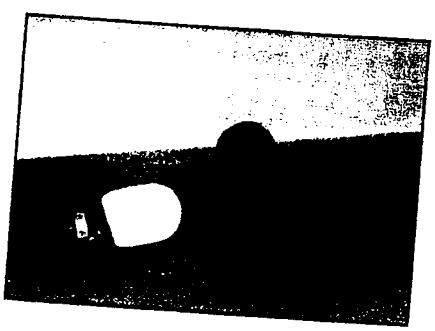
Experienced design and engineering

Final Design with ProEngineering [illegible]

Substrates [illegible]ned and mass [illegible] [illegible]r custom m[illegible]

[illegible] finishes

Coatings designed for [illegible]
IR, Visible and UV



When you need the Competitive Edge, Hardric can provide you with precision optics from Concept through Production

HARDRIC LABORATORIES

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Web: www.hardric.com

$$1000\ \text{m} = 1\ \text{kilometer} = 1\ \text{km}$$
$$1000\ \text{V} = 1\ \text{kilovolt} = 1\ \text{kV}$$
$$1\,000\,000\ \Omega = 1\ \text{megohm} = 1\ \text{M}\Omega$$
$$0.000\,000\,001\ \text{s} = 1\ \text{nanosecond} = 1\ \text{ns}$$

Only one prefix is to be employed for a unit. For example:

$$1000\ \text{kg} = 1\ \text{Mg} \qquad \text{not } 1\ \text{kkg}$$
$$10^{-9}\ \text{s} = 1\ \text{ns} \qquad \text{not } 1\ \text{m}\mu\text{s}$$
$$1\,000\,000\ \text{m} = 1\ \text{Mm} \qquad \text{not } 1\ \text{kkm}$$

Also, when a unit is raised to a power, the power applies to the whole unit including the prefix. For example:

$$\text{km}^2 = (\text{km})^2 = (1000\ \text{m})^2 = 10^6\ \text{m}^2 \qquad \text{not } 1000\ \text{m}^2$$

Table 1. Basic units of the International System

Quantity	*Name of unit*	*Unit symbol*
[illegible]	[illegible]	[illegible]

Table 2. Derived units of the International System

Quantity	*Name of unit*	*Unit symbol or abbreviation, where differing from basic form*	*Unit expressed in terms of basic or supplementary units**
area	square meter		m^2
volume	cubic meter		m^3
frequency	hertz, cycle per second†	Hz	s^{-1}
density	kilogram per cubic meter		kg/m^3
velocity	meter per second		m/s
angular velocity	radian per second		rad/s
acceleration	meter per second squared		m/s^2
angular acceleration	radian per second squared		rad/s^2
volumetric flow rate	cubic meter per second		m^3/s
force	newton.	N	$kg\ m/s^2$
surface tension	newton per meter, joule per square meter	N/m, J/m^2	kg/s^2
pressure	newton per square meter, pascal†	N/m^2, Pa†	$kg/m\ s^2$
viscosity, dynamic	newton-second per square meter, poiseuille†	$N\ s/m^2$, Pl†	kg/m s
viscosity, kinematic	meter squared per second		m^2/s
work, torque, energy, quantity of heat	joule, newton-meter, watt-second	J, N m, W s	$kg\ m^2/s^2$
power, heat flux	watt, joule per second	W, J/s	$kg\ m^2/s^3$
heat flux density	watt per square meter	W/m^2	kg/s^3
volumetric heat release rate	watt per cubic meter	W/m^3	$kg/m\ s^3$
heat transfer coefficient	watt per square meter degree	W/m^2 deg	kg/s^3 deg
heat capacity (specific)	joule per kilogram degree	J/kg deg	m^2/s^2 deg
capacity rate	watt per degree	W/deg	$kg\ m^2/s^3$ deg
thermal conductivity	watt per meter degree	W/m deg, $\frac{Jm}{s\ m^2\ deg}$	$kg\ m/s^3$ deg
quantity of electricity	coulomb	C	A s
electromotive force	volt	V, W/A	$kg\ m^2/A\ s^3$
electric field strength	volt per meter		V/m
electric resistance	ohm	Ω, V/A	$kg\ m^2/A^2\ s^3$
electric conductivity	ampere per volt meter	A/V m	$A^2s^3/kg\ m^3$
electric capacitance	farad	F, A s/V	$A^2s^4/kg\ m^2$
magnetic flux	weber	Wb, V s	$kg\ m^2/A\ s^2$
inductance	henry	H, V s/A	$kg\ m^2/A^2s^2$
magnetic permeability	henry per meter	H/m	$kg\ m/A^2s^2$
magnetic flux density	tesla, weber per square meter	T, Wb/m^2	$kg/A\ s^2$
magnetic field strength	ampere per meter		A/m
magnetomotive force	ampere		A
luminous flux	lumen	lm	cd sr
luminance	candela per square meter		cd/m^2
illumination	lux, lumen per square meter	lx, lm/m^2	$cd\ sr/m^2$

*Supplementary units are: plane angle, radian (rad), solid angle, steradian (sr).
†Not used in all countries.

Conversion factors for the measurement systems

Because it will take some years for all scientists and engineers to convert to the SI, this dictionary has retained the U.S. Customary and metric systems. Conversion factors between the two systems and SI are given in **Table 5** for some prevalent units; in each of the subtables the user proceeds as follows:

To convert a quantity expressed in a unit in the left-hand column to the equivalent in a unit in the top row of a subtable, multiply the quantity by the factor common to both units.

The factors have been carried out to seven significant figures, as derived from the fundamental constants and the definitions of the units. However, this does not m that the factors are always known to that accur Numbers followed by ellipses are to be continuec definitely with repetition of the same pattern of di Factors written with fewer than seven significant di are exact values. Numbers followed by an asterisk definitions of the relation between the two units. "G. UNITS OF ENERGY," the electrical units are thos terms of which certification of standard cells, stand resistances, and so forth, is made by the Natio Bureau of Standards; unless otherwise indicated, electrical units are absolute.

Table 5. Conversion factors for the U.S. Customary System, metric system, and International System

A. UNITS OF LENGTH

Units	cm	m	in.	ft	yd	mile
1 cm	= 1	0.01*	0.3937008	0.03280840	0.01093613	6.213712×10^{-6}
1 m	= 100.	1	39.37008	3.280840	1.093613	6.213712×10^{-4}
1 in.	= 2.54*	0.0254	1	0.08333333...	0.02777777...	1.578283×10^{-5}
1 ft	= 30.48	0.3048	12.*	1	0.3333333...	1.893939×10^{-4}...
1 yd	= 91.44	0.9144	36.	3.*	1	5.681818×10^{-4}...
1 mile	$= 1.609344 \times 10^{5}$	1.609344×10^{3}	6.336×10^{4}	5280.*	1760.	1

B. UNITS OF AREA

Units	cm^2	m^2	$in.^2$	ft^2	yd^2	$mile^2$
1 cm^2	= 1	10^{-4}*	0.1550003	1.076391×10^{-3}	1.195990×10^{-4}	3.861022×10^{-11}
1 m^2	$= 10^{4}$	1	1550.003	10.76391	1.195990	3.861022×10^{-7}
1 $in.^2$	= 6.4516*	6.4516×10^{-4}	1	6.944444×10^{-3}...	7.716049×10^{-4}	2.490977×10^{-10}
1 ft^2	= 929.0304	0.09290304	144.*	1	0.1111111...	3.587007×10^{-8}
1 yd^2	= 8361.273	0.8361273	1296.	9.*	1	3.228306×10^{-7}
1 $mile^2$	$= 2.589988 \times 10^{10}$	2.589988×10^{6}	4.014490×10^{9}	2.78784×10^{7}*	3.0976×10^{6}	1

C. UNITS OF VOLUME

Units	cm^3	liter	$in.^3$	ft^3	qt	gal
1 cm^3	= 1	10^{-3}	0.06102374	3.531467×10^{-5}	1.056688×10^{-3}	2.641721×10^{-4}
1 liter	= 1000.*	1	61.02374	0.03531467	1.056688	0.2641721
1 $in.^3$	= 16.38706*	0.01638706	1	5.787037×10^{-4}	0.01731602	4.329004×10^{-3}
1 ft^3	= 28316.85	28.31685	1728.*	1	2.992208	7.480520
1 qt	= 946.353	0.946353	57.75	0.0342014	1	0.25
1 gal (U.S.)	= 3785.412	3.785412	231.*	0.1336806	4.*	1

Table 5. Conversion factors for the U.S. Customary System, metric system, and International System (cont.)

D. UNITS OF MASS

Units	g	kg	oz	lb	metric ton	ton
1 g	= 1	10^{-3}	0.03527396	2.204623×10^{-3}	10^{-6}	1.102311×10^{-6}
1 kg	= 1000.	1	35.27396	2.204623	10^{-3}	1.102311×10^{-3}
1 oz (avdp)	= 28.34952	0.02834952	1	0.0625	2.834952×10^{-5}	$5. \times 10^{-4}$
1 lb (avdp)	= 453.5924	0.4535924	16.*	1	4.535924×10^{-4}	0.0005
1 metric ton	= 10^{6}	1000.*	35273.96	2204.623	1	1.102311
1 ton	= 907184.7	907.1847	32000.	2000.*	0.9071847	1

E. UNITS OF DENSITY

Units	g cm^{-3}	g l.$^{-1}$	oz in.$^{-3}$	lb in.$^{-3}$	lb ft^{-3}	lb gal^{-1}
1 g cm^{-3}	= 1	1000.	0.5780365	0.03612728	62.42795	8.345403
1 g l.$^{-1}$	= 10^{-3}	1	5.780365×10^{-4}	3.612728×10^{-5}	0.06242795	8.345403×10^{-3}
1 oz in.$^{-3}$	= 1.729994	1729.994	1	0.0625	108.	14.4375
1 lb in.$^{-3}$	= 27.67991	27679.91	16.	1	1728.	231.
1 lb ft^{-3}	= 0.01601847	16.01847	9.259259×10^{-3}	5.7870370×10^{-4}	1	0.1336806
1 lb gal^{-1}	= 0.1198264	119.8264	4.749536×10^{-3}	4.3290043×10^{-3}	7.480519	1

F. UNITS OF PRESSURE

Units	dyn cm^{-2}	bar	atm	kg (wt) cm^{-2}	mmHg (Torr)	in. Hg	lb (wt) in.$^{-2}$
1 dyn cm^{-2}	= 1	10^{-6}	9.869233×10^{-7}	1.019716×10^{-6}	7.500617×10^{-4}	2.952999×10^{-5}	1.450377×10^{-5}
1 bar	= 10^{6}*	1	0.9869233	1.019716	750.0617	29.52999	14.50377
1 atm	= 1013250.*	1.013250	1	1.033227	760.	29.92126	14.69595
1 kg (wt) cm^{-2}	= 980665.	0.980665	0.9678411	1	735.5592	28.95903	14.22334
1 mmHg (Torr)	= 1333.224	1.333224×10^{-3}	1.3157895×10^{-3}	1.3595099×10^{-3}	1	0.03937008	0.01933678
1 in. Hg	= 33863.88	0.03386388	0.03342105	0.03453155	25.4	1	0.4911541
1 lb (wt) in.$^{-2}$	= 68947.57	0.06894757	0.06804596	0.07030696	51.71493	2.036021	1

G. UNITS OF ENERGY

Units	g mass (energy equiv)	J	int J	cal	cal$_{IT}$	Btu$_{IT}$	kW hr	hp hr	ft-lb (wt)	cu ft-lb (wt) in.$^{-2}$	l.-atm
1 g mass (energy equiv)	= 1	8.987554×10^{13}	8.986071×10^{13}	2.148077×10^{13}	2.146640×10^{13}	8.518558×10^{10}	2.496543×10^{7}	3.347919×10^{7}	6.628880×10^{13}	4.603399×10^{11}	8.870026×10^{11}
1 J	= 1.112650×10^{-14}	1	0.999835	0.2390057	0.2388459	9.478172×10^{-4}	$2.777777... \times 10^{-7}$	3.725062	0.7375622	5.121960×10^{-3}	9.869233×10^{-3}
1 int J	= 1.112833×10^{-14}	1.000165	1	0.2390452	0.2388853	9.479735×10^{-4}	2.778236×10^{-7}	3.725676×10^{-7}	0.7376839	5.122805×10^{-3}	9.870862×10^{-3}
1 cal	= 4.655327×10^{-14}	4.184	4.183310	1	0.9993312	3.965667×10^{-3}	$1.1622222... \times 10^{-6}$	1.558562×10^{-6}	3.085960	2.143028×10^{-2}	0.04129287
1 cal$_{IT}$	= 4.658442×10^{-14}	4.1868	4.186109	1.000669	1	3.968321×10^{-3}	1.163000×10^{-6}	1.559609×10^{-6}	3.088025	2.144462×10^{-2}	0.04132050

continued

Table 5. Conversion factors for the U.S. Customary System, metric system, and International System (cont.)

G. UNITS OF ENERGY *(cont.)*

Units	g mass (energy equiv)	J	int J	cal	cal_{IT}	Btu_{IT}	kW hr	hp hr	ft-lb (wt)	cu ft-lb (wt) in.$^{-2}$	l.-atm
1 Btu_{IT}	$= 1.173908 \times 10^{-11}$	1055.056	1054.882	252.1644	251.9958*	1	2.930711×10^{-4}	3.930148×10^{-4}	778.1693	5.403953	10.41259
1 kW hr	$= 4.005539 \times 10^{-8}$	3600000.*	3599406.	860420.7	859845.2	3412.142	1	1.341022	2655224.	18439.06	35529.24
1 hp hr	$= 2.986930 \times 10^{-8}$	2684519.	2684077.	641615.6	641186.5	2544.33	0.7456998	1	1980000.*	13750.	26494.15
1 ft-lb (wt)	$= 1.508550 \times 10^{-14}$	1.355818	1.355594	0.3240483	0.3238315	1.285067×10^{-3}	3.766161×10^{-7}	$5.050505... \times 10^{-7}$	1	$6.944444... \times 10^{-3}$	0.01338088
1 cu ft-lb (wt) in.$^{-2}$	$= 2.172313 \times 10^{-12}$	195.2378	195.2056	46.66295	46.63174	0.1850497	5.423272×10^{-5}	$7.272727... \times 10^{-5}$	144.*	1	1.926847
1 l.-atm	$= 1.127392 \times 10^{-12}$	101.3250	101.3083	24.21726	24.20106	0.09603757	2.814583×10^{-5}	3.774419×10^{-5}	74.73349	0.5189825	1

Symbols and atomic numbers for the chemical elements*

Name	Symbol	At. no.	Name	Symbol	At. no.	Name	Symbol	At. no.	Name	Symbol	At. no.
Actinium	Ac	89	Erbium	Er	68	Mercury	Hg	80	Samarium	Sm	62
Aluminum	Al	13	Europium	Eu	63	Molybdenum	Mo	42	Scandium	Sc	21
Americium	Am	95	Fermium	Fm	100	Neodymium	Nd	60	Selenium	Se	34
Antimony	Sb	51	Fluorine	F	9	Neon	Ne	10	Silicon	Si	14
Argon	Ar	18	Francium	Fr	87	Neptunium	Np	93	Silver	Ag	47
Arsenic	As	33	Gadolinium	Gd	64	Nickel	Ni	28	Sodium	Na	11
Astatine	At	85	Gallium	Ga	31	Niobium	Nb	41	Strontium	Sr	38
Barium	Ba	56	Germanium	Ge	32	Nitrogen	N	7	Sulfur	S	16
Berkelium	Bk	97	Gold	Au	79	Nobelium	No	102	Tantalum	Ta	73
Beryllium	Be	4	Hafnium	Hf	72	Osmium	Os	76	Technetium	Tc	43
Bismuth	Bi	83	Helium	He	2	Oxygen	O	8	Tellurium	Te	52
Boron	B	5	Holmium	Ho	67	Palladium	Pd	46	Terbium	Tb	65
Bromine	Br	35	Hydrogen	H	1	Phosphorus	P	15	Thallium	Tl	81
Cadmium	Cd	48	Indium	In	49	Platinum	Pt	78	Thorium	Th	90
Calcium	Ca	20	Iodine	I	53	Plutonium	Pu	94	Thulium	Tm	69
Californium	Cf	98	Iridium	Ir	77	Polonium	Po	84	Tin	Sn	50
Carbon	C	6	Iron	Fe	26	Potassium	K	19	Titanium	Ti	22
Cerium	Ce	58	Krypton	Kr	36	Praseodymium	Pr	59	Tungsten	W	74
Cesium	Cs	55	Lanthanum	La	57	Promethium	Pm	61	Uranium	U	92
Chlorine	Cl	17	Lawrencium	Lr (Lw)	103	Protactinium	Pa	91	Vanadium	V	23
Chromium	Cr	24	Lead	Pb	82	Radium	Ra	88	Xenon	Xe	54
Cobalt	Co	27	Lithium	Li	3	Radon	Rn	86	Ytterbium	Yb	70
Copper	Cu	29	Lutetium	Lu	71	Rhenium	Re	75	Yttrium	Y	39
Curium	Cm	96	Magnesium	Mg	12	Rhodium	Rh	45	Zinc	Zn	30
Dysprosium	Dy	66	Manganese	Mn	25	Rubidium	Rb	37	Zirconium	Zr	40
Einsteinium	Es	99	Mendelevium	Md	101	Ruthenium	Ru	44			

*Elements 104 and 105 have been reported, but no official names or symbols have yet been assigned.

MATERIAL SAFETY DATA SHEET - NO. M114

BERYLLIUM SOLID

NEW: 12-01-92
Prepared By: Marc Kolanz
Thomas N. Markham, M.D.
Pages: 5

CUSTOMER SERVICE

Brush Wellman Inc.
Environmental Control Operations
14710 W. Portage River S. Road
Elmore, Ohio 43416-9502

Phone: (419) 862-2745
Telefax: (419) 862-4177

24-Hr. EMERGENCY ASSISTANCE

Brush Wellman: (419) 862-2745
Chemtrec: (800) 424-9300

I. PRODUCT IDENTIFICATION

COMMON NAME: Beryllium

CHEMICAL NAME: Beryllium

LABEL IDENTITY: Beryllium Product

CHEMICAL FAMILY: Metal

SYNONYMS: Beryllium Metal
Metallic Beryllium

FORMULA: Be

II. CHEMICAL COMPOSITION AND PHYSICAL PROPERTIES

CHEMICAL COMPOSITION Beryllium: 100%

PHYSICAL PROPERTIES

Atomic Number:	4
Atomic Weight:	9.01
Boiling Point:	2970°C
Evaporation Rate:	NA
Freezing Point:	NA
Odor:	None
pH:	NA
Physical State:	Solid Shape
Radioactivity:	NA
Solubility in Water:	None
Sublimes At:	NA
Vapor Density (Air = 1):	NA
Vapor Pressure (mmHg):	NA
% Volatiles By Volume:	None
Color:	Gray Metallic
Melting Point (°F):	2345
Melting Point (°C):	1285
Density (g/cc):	1.85

NA = Not Applicable

III. OCCUPATIONAL STANDARDS AND REFERENCES

CONSTITUENTS	OSHA (1989)*			ACGIH (1989)*			NIOSH RTECS NUMBER
	PEL	CEILING	PEAK	TLV	TLV-STEL	CAS NUMBER	
Beryllium	0.002	0.005	0.025	0.002	NA	7440-41-7	DS1750000

**ALL CONCENTRATIONS ARE AS ELEMENTAL BERYLLIUM IN MILLIGRAMS PER CUBIC METER OF AIR*
(at the concentrations noted above, this constituent may not be visible to the human eye)

ACGIH = American Conference of Governmental Industrial Hygienists
OSHA = Occupational Safety and Health Administration
PEL = Eight Hour Average Permissible Exposure Limit (OSHA)
CEILING = Not To Be Exceeded Except For Peak Limit (OSHA)
PEAK = 30 Minute Maximum Duration Concentration Above Ceiling Limit (OSHA)
TLV = Eight Hour Average Threshold Limit Value (ACGIH)
TLV-STEL = 15 Minute Short Term Exposure Limit (ACGIH)
CAS = Chemical Abstract Service
NIOSH = National Institute for Occupational Safety and Health
RTECS = Registry of Toxic Effects of Chemical Substances

IV. FIRE, EXPLOSION, AND REACTIVITY INFORMATION

Flash Point	Not applicable to solids.
Explosive Limits	Not applicable to solids.
Extinguishing Media	Only in powder or other finely divided form does beryllium present a special fire problem. To extinguish a metal powder fire, use Class D fire extinguishing powder.
Unusual Fire and Explosion Hazards	Do not use water to extinguish fires around operations involving molten metal due to the potential for steam explosions. In addition, water may disassociate when in contact with burning beryllium powder or chips releasing flammable hydrogen gas which could burn and result in an explosion. Ventilation duct work which has accumulated a fine coating of beryllium dust on its internal surface poses a potentially serious fire hazard. Extinguish using Class D fire extinguisher media and shut down or isolate the affected portion of the ventilation system. Because of this potential risk, sources of ignition such as flame, spark from machining of other materials, welding spark, etc. must not be allowed to enter the ventilation duct work. Also, duct work must be made of non-combustible material. See Section VII for further information regarding personal protective measures.
Special Fire Fighting Procedures	If this material becomes airborne as a respirable particulate during a fire situation, pressure-demand self-contained breathing apparatus must be worn by firefighters or any other persons potentially exposed to the metal fumes.
General Reactivity	This material is stable.
Incompatibility (materials to avoid)	Avoid contact with mineral acids and oxidizing agents which may generate hydrogen gas. Hydrogen gas can be an explosion hazard.
Hazardous Decomposition Products	Melting and dross handling of powdering operations can emit airborne dusts or fumes. Refer to Section III for permissible exposure limits.
Hazardous Polymerization	Will not occur.

V. HEALTH HAZARD INFORMATION

PRIMARY ROUTES OF EXPOSURE

INHALATION: An exposure to airborne beryllium in excess of the occupational standard can occur when machining, melting, casting, dross handling, pickling, welding, grinding, sanding, polishing, milling, crushing, or otherwise abrading the surface of solid beryllium in a manner which generates finely divided particles.

Machining operations conducted under a flood of liquid coolant usually require local exhaust ventilation. The cycling through a machine of liquid lubricant/coolant containing finely divided beryllium in suspension can result in the concentration building to a point where the particulate may become airborne during use. A filter, centrifuge, or settling chamber can be installed in-line if necessary.

The potential for exposures also may occur during repair or maintenance activities on contaminated equipment such as: furnace rebuilding, maintenance or repair of air cleaning equipment, structural renovation, welding, etc.

INGESTION: There are no known cases of illness resulting from ingestion of beryllium. Ingestion can occur from hand, clothing, food, and drink contact with metal dust, fume, or powder during hand to mouth activities such as eating, drinking, smoking, nail biting, etc. This product is not intended for internal consumption. As a standard hygiene practice, hands should be washed before eating or smoking.

SKIN: This product is in an insoluble form and does not pose a potential for an allergic dermal response or skin absorption and can be safely handled with bare hands. Skin abrasion may cause irritation. See Section VI for additional information.

EYES: Injury to the eyes can result from particulate irritation or mechanical injury to the cornea or conjunctiva by dust or particulate. Exposure may result from direct contact with airborne particulate (chips, dust or powder) or contact to the eye of contaminated hands or clothing.

EFFECTS OF OVEREXPOSURE

ACUTE *(immediate or near-term health effects):* This product is insoluble and does not cause acute health effects.

CHRONIC *(long-term health effects):* Overexposure to airborne beryllium particulate may cause a serious lung disease, in certain sensitive individuals, called chronic beryllium disease (chronic berylliosis). Chronic beryllium disease is a condition in which the tissues of the lungs become inflamed, restricting the exchange of oxygen between the lungs and the bloodstream. Symptoms may include cough, chest pain, shortness of breath, weight loss, weakness, and fatigue. Long-term effects may include loss of lung function, fibrosis, or subsequent secondary effects on the heart with eventual permanent impairment.

CARCINOGENIC REFERENCES: Hazard communication regulations of the U.S. Occupational Safety & Health Administration require that caution labels for materials listed as potential carcinogens in either the International Agency for Cancer Research Monograph Series or the National Toxicology Program Annual Report on carcinogens must contain a cancer warning. Beryllium has been so listed principally on animal tests and therefore, as shipped by Brush, this material bears a label identifying it as a potential cancer hazard.

V. HEALTH HAZARD INFORMATION

MEDICAL CONDITIONS AGGRAVATED BY EXPOSURE: Persons with impaired pulmonary function, airway diseases, or conditions such as asthma, emphysema, chronic bronchitis, etc. may incur further impairment if excessive concentrations of dust or fume are inhaled. If prior damage or disease to the neurologic (nervous), circulatory, hematologic (blood), or urinary (kidney) systems has occurred, proper screening or examinations should be conducted on individuals who may be exposed to further risk where handling and use of this material may cause excessive exposure.

VI. EMERGENCY AND FIRST AID PROCEDURES

INHALATION: Breathing difficulty caused by inhalation of dust or fume requires immediate removal to fresh air. Although no cases in which a person stopped breathing as a result of exposure are known, if breathing has stopped, perform artificial respiration and obtain medical help.

INGESTION: Swallowing metal powder or dust can be treated by having the affected person drink large quantities of water and attempting to induce vomiting if conscious. Obtain medical help.

SKIN: Skin cuts and abrasions can be treated by standard first aid. Skin contamination with dust or powder can be removed by washing with soap and water. If irritation persists obtain medical help. Accidental implantation of this material beneath the skin requires it be removed to prevent infection or development of a corn-like lesion.

EYES: Dust or powder should be flushed from the eyes with copious amounts of clean water. If irritation persists obtain medical help. Contact lenses should not be worn when working with metal dusts and powders because the contact lens must be removed to provide adequate treatment.

VII. OCCUPATIONAL CONTROL MEASURES

VENTILATION AND ENGINEERING CONTROLS: Whenever possible the use of local exhaust ventilation or other engineering controls is the preferred method of controlling exposure to airborne dust and fume to meet established occupational exposure limits. Where utilized, pickups on flexible ventilation lines should be positioned as close to the source of airborne contamination as possible. Disruption of the airflow in the area of a local exhaust inlet, such as by a man cooling fan, should be avoided. Ventilation equipment should be checked regularly to ensure it is functioning properly. Ventilation training is recommended for all users.

RESPIRATORY PROTECTION: When potential exposures are above the occupational limits shown in Section III, approved respirators must be used as specified by an Industrial Hygienist or other qualified professional. Respirator users should be medically evaluated to determine if they are physically capable of wearing a respirator. Quantitative and/or qualitative fit testing and respirator training must be satisfactorily completed by all personnel prior to respirator use in an environment where concentrations of airborne fumes or dusts may exceed the occupational standards. Users of any style respirator must be clean shaven on those areas of the face where the respirator seal contacts the face. Exposure to unknown concentrations of fumes or dusts requires the wearing of a pressure-demand airline respirator or pressure-demand self-contained breathing apparatus. Pressure-demand airline respirators are recommended for jobs when high potential exposures such as changing bags in a baghouse air cleaning device.

HOUSEKEEPING: Vacuum or wet cleaning methods are recommended for dust removal. Be certain to deenergize electrical systems as necessary before beginning wet cleaning. Vacuum cleaners with high efficiency particulate air (HEPA) filters are the recommended type. The use of compressed air to remove dusts should be avoided as such an activity can result in unnecessary short-term elevated exposures to dusts.

MAINTENANCE: During repair or maintenance activities the potential exists for exposures to beryllium in excess of the occupational standard. Under these circumstances, protecting workers can require the use of specific work practices or procedures involving the combined use of ventilation, wet methods, respiratory protection, decontamination, special protective clothing, and when necessary, restricted work zones.

WELDING: In accordance with OSHA regulation 29 CFR 1910.252 welding of beryllium is regulated as follows: Welding or cutting indoors, outdoors, or in confined spaces involving beryllium-containing base or filler metals shall be done using local exhaust ventilation and airline respirators unless atmospheric tests under the most adverse conditions have established that the workers' exposure is within the acceptable concentrations defined by 29 CFR 1910.1000. In all cases, workers in the immediate vicinity of the welding or cutting operations shall be protected as necessary by local exhaust ventilation or airline respirators. Please note: Metallic beryllium is normally welded. Satisfactory welds are only achieved using electron beam welding.

OTHER PROTECTIVE EQUIPMENT: No protective equipment or clothing is required when handling solid forms. Protective clothing such as fire retardant clothing, and molten metal splash resistant garments (ie: coats, hats, hoods, pants, shoes, gloves) should be worn as necessary to protect from accidental molten metal splash. Protective overgarments or work clothing should be worn by persons who may become contaminated with dusts or powders during activities such as furnace rebuilding, air cleaning equipment bag changes, furnace tending, etc. Contaminated work clothing and overgarments should be managed in such a manner so as to prevent secondary exposure to persons such as laundry operators and to prevent contamination to personal clothing. Never use compressed air to clean work clothing.

PROTECTIVE GLOVES: Wear gloves to prevent metal cuts and skin abrasions particularly during handling.

EYE PROTECTION: Wear safety glasses, goggles, face shield or welders helmet when risk of eye injury is present particularly during melting, casting, machining, grinding, welding, powder handling, etc.

RECOMMENDED MONITORING PROCEDURES

ENVIRONMENTAL SURVEILLANCE: Exposures to beryllium should be determined by having air samples taken in the employee breathing zone, work area, and department. The frequency and type of air sampling should be as specified by an Industrial Hygienist or other qualified professional. Air sample results should be made available to employees.

MEDICAL SURVEILLANCE: Periodic lung function tests, chest x-rays, and physical examinations should be used to monitor the potential effects of dust or fume exposure.

VIII. ENVIRONMENTAL PROTECTION INFORMATION

STEPS TO BE TAKEN IF MATERIAL IS RELEASED OR SPILLED: In solid form this material poses no health or environmental risk. If this material is in powder or dust form, establish a restricted entry zone based on the severity of the spill. Persons entering the restricted zone must wear adequate respiratory protection and protective clothing appropriate for the severity of the spill. Cleanup should be conducted with a vacuum system utilizing a high efficiency particular air filtration system followed by wet cleaning methods. Special care must be taken when changing filters on HEPA vacuum cleaners when used to clean up potentially toxic materials. Caution should be taken to minimize airborne generation of powder or dust and avoid contamination of air and water. Depending upon the quantity of material released, fine powder or dust spills to the environment may require reporting to the National Response Center at (800) 424-8802 as well as the State Emergency Response Commission and Local Emergency Planning Committee.

SOLID WASTE MANAGEMENT: The U.S. Environmental Protection Agency has classified beryllium dust (P015) as a hazardous waste under the Resource Conservation and Recovery Act (RCRA). In Section 40 CFR 261.33(e) of RCRA, beryllium dust is considered hazardous when it is in the form of a "discarded commercial chemical product, off-specification species, container residue and spill residue, thereof. "It is our understanding this designation only applies to commercially pure products or manufacturing intermediates in which beryllium is the "sole active ingredient." Due to the limited scope of this definition, we believe the only form of beryllium to which it applies is waste metallic beryllium dust in the form of commercially pure metallic beryllium powder.

Beryllium scrap, chips, and powder are normally recycled. In cases where this is not justified, we recommend any off-specification metallic beryllium dust or powder be sealed within two plastic bags and then placed within a DOT container approved for flammable solids. The outer container must be labeled with the appropriate EPA hazardous waste label and DOT hazard warning label(s) and shipped under a uniform hazardous waste manifest to an approved hazardous waste management facility. We suggest the above procedure, with the exception of the hazardous waste manifest and hazardous waste container label, also be followed when disposing of dust collector filters contaminated with metallic beryllium dust.

AMBIENT AIR EMISSIONS: Beryllium users involving outplant emissions are subject to the National Emission Standard for Beryllium as promulgated by EPA (40 CFR 61, Subpart C). The National Emission standard for beryllium is 0.01 micrograms per cubic meter (30 day average) in ambient air for those production facilities which have been qualified to be regulated through ambient air monitoring. Other facilities must meet a 10 gram per 24-hour total site emission limit. Most process air emission sources exhausting outside a production building will require an air permit from a local and/or state air pollution control agency. The use of air cleaning equipment may be necessary to achieve the desired level of control. Tempered makeup air should be provided to prevent excessive negative pressure in a building. Direct recycling of cleaned process exhaust air is not recommended. Plant exhausts should be located so as not to re-enter the plant through makeup air or other inlets. Regular maintenance, inspection and monitoring of air cleaning equipment operating parameters is important to ensure adequate efficiency is maintained.

WASTEWATER: Wastewater regulations can vary considerably. Contact your local and state governments to determine what conditions apply.

TOXIC SUBSTANCES CONTROL ACT: Beryllium (CAS #7440-41-7) is listed on the TSCA Chemical Substance Inventory of Existing Chemical Substances.

IX. SARA TITLE III REPORTING REQUIREMENTS

On February 16, 1988 the U.S. Environmental Protection Agency (EPA) issued a final rule that implements the requirements of the Superfund Amendments and Reauthorization Act (SARA) Title III, Section 313 (53) Federal Register 4525. Title III is the portion of SARA concerning emergency planning and community right-to-know issues. Section 313 covers annual emission reporting on defined chemicals which are manufactured, processed or used at certain U.S. Industrial facilities.

Beryllium is reportable under Section 313. The Chemical Abstracts Services number is provided in Section III of this Material Safety Data Sheet.

You may obtain additional information by calling the EPA SARA Title III Hotline at 1-800-535-0202 (or 202-555-1411).

There are no hazardous material regulations of the U.S. Department of Transportation which apply to the packaging and labeling of this material as shipped by Brush Wellman.

Hazard communication regulations of the U.S. Occupational Safety and Health Administration require that this material be labeled. Following is the label text which accompanies this product during shipment.

BERYLLIUM PRODUCT

DANGER — INHALATION OF DUST OR FUMES MAY CAUSE SERIOUS CHRONIC LUNG DISEASE

POTENTIAL CANCER HAZARD BASED PRINCIPALLY ON ANIMAL TESTS

This product contains beryllium. Overexposure to beryllium by inhalation may cause berylliosis, a serious chronic lung disease. Hazard Communication Regulations of the Occupational Safety & Health Administration require that caution labels for materials listed as potential carcinogens in either the International Agency for Cancer Research Monograph Series or the National Toxicology Program Annual Report on Carcinogens must contain a cancer warning. Beryllium has been so listed.

- **If processing produces dust or fumes, use only with exhaust ventilation or other controls designed to meet OSHA standards.**
- **Sold for manufacturing purposes only.**

See Material Safety Data Sheets on file with your employer for further details concerning OSHA standards and precautionary measures.

Assistance in establishing safe procedures may be obtained by contacting Brush Wellman Inc., 14710 W. Portage River S. Road, Elmore, Ohio 43416-9502, telephone: 419-862-2745.

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*Label may vary in size
*Label color gray/white (solid)

IMPORTANT: If you have any questions or require additional information regarding the materials described in this Material Safety Data Sheet, please telephone or write to Environmental Control Operations at the location given on page 1.

NATLSCO

TECHNICAL BULLETIN

IH 7.

RESPIRATORY PROTECTIVE DEVICES

INTRODUCTION

In the control of occupational diseases caused by breathing contaminated air, the primary objective should be to prevent the air from becoming contaminated. If industrial work processes present hazards of exposure to harmful vapors, gases, dusts, mists or fumes, these processes should be enclosed or ventilated to eliminate or minimize the hazards. However, there will always be circumstances in which engineering controls will be impractical, inapplicable, or ineffective. In these situations, respiratory protective equipment should be provided to workers exposed to possible danger. In addition to their employment as a control measure in occupational exposures, respiratory protective devices are also essential in emergencies that may arise from failure or improper use of other control equipment.

From a practical standpoint, respiratory protective devices will not be worn continously by workmen because of the discomfort involved. Therefore, protective respiratory equipment should be considered a last resort, or as standby protection, but never as a substitute for effective engineering controls.

TYPES OF RESPIRATORY PROTECTION

Respiratory protective devices fall into two broad groupings on the basis of their mode of functioning: A. atmosphere supplying respirators and B. air-purifying respirators.

A. Atmosphere-supplying respirators provide a respirable atmosphere to the wearer independent of his immediate atmospheric environment. They are divided into two main subgroups:

1. Self-contained breathing apparatus (SCBA)

   The unique feature of all types of self-contained breathing apparatus is that the wearer need not be connected to a stationary air source, such as a compressor. Instead, enough air or oxygen for up to four hours is carried on the person. For this reason, this type of respirator provides protection against all types of atmospheric contaminants in any concentration that can be endured by the skin. There are two basic classifications of SCBA's - "closed circuit" and "open circuit".

In the closed circuit category, the air is rebreathed after the exhaled carbon dioxide has been removed and the oxygen content restored. These types of devices are designed for longer continous use than the open circuit devices which exhaust the exhaled air to the atmosphere instead of recirculating it. Because closed circuit SCBA's operate under negative pressure, they have limited approval for use in atmospheres Immediately Dangerous to Life & Health (IDLH). They are generally restricted to mine rescue.

Note: Immediately Dangerous to Life & Health (IDLH) is defined by NIOSH-MESA as "Conditions that pose an immediate threat to life or health or conditions that pose an immediate threat of severe exposure to contaminants such as radio-active materials which are likely to have adverse cumulative or delayed effects on health.

Two factors are considered when establishing IDLH concentrations:

1. The worker must be able to escape without losing his life or suffering permanent health damage within 30 minutes. Thirty minutes is considered by OSHA as the maximum permissible exposure time for escape.

2. The worker must be able to escape without severe eye or respiratory irritation or other reactions that could inhibit escape.

2. Supplied-air respirators

The distinguishing feature of supplied-air respirators is that air is supplied from a staionary, remote source to the wearer through a hose. The air supplying respirators are divided into three types, namely hosemasks, air line respirators, and abrasive blasting hoods.

Note: No supplied-air respirator is approved for use in IDLH atmospheres.

a. Hose masks supply air from an uncontaminated source through a strong, large-diameter hose. There are two basic types of hosemasks available. One has a blower, either hand- or motor operated (Type A). The other type (Type B) of hosemask has no blower and requires the wearer to inhale through the hose. The Type "A" hosemask may have a facepiece, helmet or hood, up to 300 feet of hose. Type "B" hosemask must have a tight fitting facepiece, and may have only up to 75 feet of hose.

b. Airline respirators (Type C) all use a stationary source of compressed air delivered through a high pressure hose. Type "C" respirators are available in demand, pressure-demand, and continous flow configurations. The respiratory-inlet covering may be a facepiece, helmet, hood, or complete suit. Airline respirators provide a high degree of protection, but their use is limited to atmospheres not immediately dangerous to life.

c. Abrasive Blasting Respirators (Type AE, BE, or CE,) are essentially air supplying respirators that have been modified by the addition of suitable covering to protect the head and shoulders against impact and abrasion by rebounding material. They are designed principally for use in abrasive blasting operations.

B. Air purifying respirators remove gaseous or particulate contaminants, or both, from otherwise respirable air that is inhaled by the wearer. They are of no use where an oxygen deficiency exists or in IDLH atmospheres. They are divided into the following types:

1. Mechanical filter respirators

Mechanical filter respirators offer respiratory protection against airborne particulate matter including dusts, mists, metal fumes, and smokes. They consist of a soft resilient full or half-mask facepiece. Directly attached is one of several types of mechanical filters made up of some fibrous material which removes particles by physically trapping them as air is inhaled through the material. NIOSH/MESA approves respirators for one or any combination of particulate hazards-nuisance, fibrosis-producing, and/or toxic dusts, mists, and fumes. Mechanical filter respirators have been designed for protection against atmospheres which are not immediately harmful. They do not protect against gases or vapors or against an atmosphere deficient in oxygen. There is a practical limit for the concentration in which a mechanical filter respirator should be used. If the concentration is so high that the filter must be changed several times an hour in order that the wearer can inhale without undue resistance, a more suitable type of device should be selected.

2. Chemical Cartridge Respirators

Chemical cartridge respirators afford protection against high concentrations (0.5 to .1 percent by volume, depending upon the contaminant) of certain acid gases and organic vapors by utilizing various chemical filters to purify the inhaled air. Chemical cartridge respirators are "non-emergency" respiratory protective devices and should never be used in dangerous atmospheres. It is necessary that oxygen be present at all times to support life. Facepieces are the same as for mechanical filter respirators.

3. Combination Respirators

Combination respirators use dust, mist, or fume mechanical filters plus a chemical cartridge for dual or multiple exposure. One common job where combination respirators should be used would be spray painting.

It should be noted that the same color coding used for canisters is also used for cartridges.

4. Gas Masks

A gas mask consists of a full face piece connected by a a flexible breathing tube to a canister under the chin, or that may be carried in a harness on the chest, under the arm, or on the back. The canister contains the materials for removing the contaminants and purifying the air. As no single substance has been discovered that will remove all types of gaseous and vapor contaminants, the canister fill depends upon the type of contaminant against which it is designed to protect.

It is extremely important to know the contaminants against which a canister will protect. To assist users in easy identification, a classification of gas mask canisters has been developed in conjunction with a color code. This code, an American Standard used by all manufacturers of gas masks in the United States, is given in Table I.

INSTITUTING AN EFFECTIVE RESPIRATORY PROTECTION PROGRAM

If a respirator is to do the job for which it is chosen, it must be worn properly, kept clean, and in a good operating condition. Frequently workers do not know how to wear a respirator. If it is not clean, it is unpleasant to wear. OSHA 1910.134 outlines the requirements of a proper respirator program. There are 11 "Commandments", including the following points:

A. Selection

The use of a respiratory protective device is justified only after a consideration of the factors involved indicates that the device selected will provide satisfactory protection when properly used. In selecting respirators, the questions in Table II should be considered.

Another guide for the proper selection of respiratory protection is the Respirator Protection Factor.

The respirator protection factor indicates how much protection a respirator provides. It is the ratio of the contaminant concentrations outside and inside the respirator. To apply an assigned protection factor for a particular type of respirator, one must know both the actual contaminant concentration in the work area and the established time-weighted average concentration by the respirator protection factor gives the maximum concentration of the contaminant against which the particular type of respirator may be used.

Respirator Protection Factors are shown in Table III. These should be used unless greater factors have been determined for each worker quantitatively.

Tables II, III and IV can provide enough information for choosing respirators for routine and emergency use.

B. Instruction

It is important that the wearer be properly instructed in the selection, use, and maintenance of the respirator by a competent person. No one should be permitted to wear a respirator unless he has been instructed in its use. Such instruction should cover:

1. Instruction in the nature of the hazard, whether acute, chronic, or both, and an honest appraisal of what may happen if the proper device is not used.

2. Explanation of why more positive control is not immediately feasible. This shall include recognition that a reasonable effort is being made to reduce or eliminate the need for respiratory protection.

3. A discussion of why this is the proper type of unit for the particular purpose.

4. A discussion of the device's capabilities and limitations.

5. Instruction and training in actual use (especially a respiratory protective device for emergency use) and close and frequent supervision to assure that it continues to be properly used.

6. Classroom and field training to recognize and copy with emergency situations.

   Training shall provide the men an opportunity to handle the device, have it fitted properly, test its facepiece-to-face seal, wear it in normal air for a long familiarity period, and finally, to wear it in a test atmosphere.

C. Supervision

After the wearer is instructed in the use of a respirator, he needs adequate supervision to assure that the proper device is being used for each exposure condition and that the device is in good operating condition and is being worn properly.

D. Medical Surveillance

Workers should never be assigned to any operations requiring respiratory protection until a physician has determined that they are capable physically and psychologically to perform the work using the respiratory protective equipment. Many plants have pre-employment physical examinations which aid in such evaluation, but additional checks may be necessary to determine suitability for specific assignment.

Should an employee have exposure to certain toxic materials periodic examinations such as a urinalysis or bioassay may be necessary even though the worker wears the proper respiratory protective equipment.

E. Cleaning and Disinfecting

Routinely used respirators should be cleaned after each use. If a respirator is used by only one individual, he should be briefed on the cleaning procedure. The respirator should be washed with warm water and soap, rinsed in clean warm water, and air dried in a clean place. The device should then be placed in a plastic bag for storage.

TABLE II

RESPIRATOR SELECTION WORKSHEET

1. Material-
   a. Chemical Name ______________________
   b. Trade Name ______________________
   c. Formula ______________________
   d. TLV or TWA OSHA 1910.1000 ________ Current ACGIH ________

2. Form in which it will be used-
   a. Liquid? ________ b. Solid? ________ c. Gaseous? ________
   d. If gaseous, is it an organic vapor? ________ or acid gas? ________
   other? ______________________

3. Maximum expected concentration-
   a. ________________ parts per million, or
   b. ________________ milligrams per cubic meter

4. Will material be heated?
   a. If so, to what temperature? ________________ °F.

5. What is the odor threshold of the mineral? ______________________

6. At what concentration is the material considered to be immediately dangerous to life or health? ______________________

7. Can the substance be absorbed through the skin? ______________________

8. Irritant to eyes? ________ respiratory tract? ________ skin? ________

9. At what concentration is it an irritant? ______________________

10. If the substance is known to be flammable, what are the lower and upper flammable limits, in per cent by volume? ______________________

11. What is the vapor pressure of the material? ______________________

12. Will material be mixed with other chemicals? ________ If so, give details
____
____
____

13. Any possibility of oxygen deficiency? ______________________

14. Can good ventilation of the area be maintained? ______________________

15. Will exposure be continuous? ________ or intermittent? ________

16. Will the respiratory device be used for routine exposures, or will it be used as an escape device? ______________________
____

17. Provide as much detail as possible concerning exposure conditions.
____
____
____
____

Respirators should also be disinfected at regular intervals. If the respirator is worn by the same person, disinfection once a week is probably satisfactory in most cases. A respirator that has been worn once should be disinfected before it is given to another person to wear. The compounds generally considered to be the most reliable for disinfecting respirators are:

1. a hypochlorite solution (50 parts per million of chlorine) for 2 minutes
2. an aqueous iodine solution (50 parts per million of iodine) for 2 minutes
3. a quaternary ammonium solution (200 parts per million of quaternary ammonium compounds in water with less than 500 parts per million total hardness)

Live steam or very hot water (170°F), organic solvents, and ultraviolet light should not be used in disinfecting respirators because of their injurious effects, particularly on the rubber parts.

F. Inspection and Maintenance

Washing and disinfecting of respirators affords an opportunity to inspect them for repairs. In addition, they should be inspected thoroughly on a periodic basis, the time interval depending on the apparatus, conditions of use, and storage. Equipment for emergency purposes should be inspected once a month and after each use to be sure that it will be in good condition and immediately available if an emergency arises.

When it is necessary to replace worn or deteriorated parts, only those made specifically for the device by the manufacturer should be used, and the repair work should be accomplished by experienced personnel.

G. Storage

Respirators should be stored in dustproof containers (original cartons, cases, or plastic bags) away from sunlight, heat extreme cold, and excessive moisture. A good procedure is to have a central place of storage where the respirators are kept clean. A check-out system, essentially the same as that used for tools, may be used for distribution of respirators to the proper workmen. The respirators should only be issued with the approval of an individual qualified to select the proper protection for the exposure.

H. Approvals

All respirators provided in the plant should be approved by NIOSH/MESA. Bureau of Mines approvals are no longer in effect for any respirators except SCBA's. In some cases, manufacturers of respirators will help substitute approved respirators for non-approved BOM respirators which may still be in the plant. In general, approved respirators carry an approval number prefaced with "TC" and the now non-approved Bureau of Mines respriators have a "BM" prefix to the approval number.

TABLE II

RESPIRATOR SELECTION WORKSHEET

1. Material-
   a. Chemical Name ______________________
   b. Trade Name ______________________
   c. Formula ______________________
   d. TLV or TWA OSHA 1910.1000 ________ Current ACGIH ________

2. Form in which it will be used-
   a. Liquid? __________ b. Solid? __________ c. Gaseous? ________
   d. If gaseous, is it an organic vapor? ________ or acid gas? ______
   other? ______________________

3. Maximum expected concentration-
   a. ______________ parts per million, or
   b. ______________ milligrams per cubic meter

4. Will material be heated?
   a. If so, to what temperature? ______________ °F.

5. What is the odor threshold of the mineral? ______________

6. At what concentration is the material considered to be immediately dangerous to life or health? ______________

7. Can the substance be absorbed through the skin? ______________

8. Irritant to eyes? __________ respiratory tract? ________ skin? _____

9. At what concentration is it an irritant? ______________

10. If the substance is known to be flammable, what are the lower and upper flammable limits, in per cent by volume? ______________

11. What is the vapor pressure of the material? ______________

12. Will material be mixed with other chemicals? ______ If so, give details
    ____
    ____
    ____

13. Any possibility of oxygen deficiency? ______________

14. Can good ventilation of the area be maintained? ______________

15. Will exposure be continuous? __________ or intermittent? __________

16. Will the respiratory device be used for routine exposures, or will it be used as an escape device? ______________
    ____

17. Provide as much detail as possible concerning exposure conditions.
    ____
    ____
    ____
    ____

TABLE III

RESPIRA R PROTECTION FACTORS

Type Respirator	Facepiece Pressure	Protection Factor
I. Air-Purifying		
A. Particulate Removing		
Single-Use, Dust	-	5
Quarter-Mask, Dust	-	5
Half-Mask, Dust	-	10
Half-or Quarter-Mask, Fume	-	10
Half-or Quarter-Mask, High-Efficiency	-	10
Full Facepiece, High-Efficiency	-	50
Powered, High-Efficiency, All Enclosures	+	1,000
Powered, Dust or Fume, All Enclosures	+	X
B. Gas and Vapor-Removing		
Half-Mask	-	10
Full Facepiece	-	50
II. Atmosphere-Supplying		
A. Supplied-Air		
Demand, Half-Mask	-	10
Demand, Full Facepiece	-	50
Hose Mask Without Blower, Full Facepiece	-	50
Pressure-Demand, Half-Mask	+	1,000
Pressure-Demand, Full Facepiece	+	2,000
Hose Mask With Blower, Full Facepiece	-	50
Continuous Flow, Half-Mask	+	1,000
Continuous Flow, Full Facepiece	+	2,000
Continuous Flow, Hood, Helmet, or Suit	+	2,000
B. Self-Contained Breathing Apparatus		
Open-Circuit, Demand, Full Facepiece	-	50
Open-Circuit, Pressure-Demand Full Facepiece	+	10,000
Closed-Circuit, Oxygen Tank-Type, Full Facepiece	-	50
III. Combination Respirator		
A. Any Combination of Air-Purifying and Atmosphere-Supplying Respirator	Use Minimum Protection Factor Listed Above for Type and Mod of Operation	
B. Any Combination of Supplied-Air Respirator and an SCBA		

TABLE IV

CONDITION OR TYPE OF CONTAMINANTS	RESPIRATORY PROTECTIVE DEVICE	REMARKS
Atmospheres deficient in oxygen	1. Self-contained breathing device	Atmospheres deficient in oxygen may be immediately dangerous to life.
Very high concentrations of toxic gases and vapors (2 or 3%)	1. Self-contained oxygen apparatus	High concentrations of many gases and vapors are immediately dangerous to life. Final choice will depend on working conditions. Gas masks would afford some protection, but in high concentrations, absorbants would be used up rapidly.
Moderately high concentrations of toxic gases and vapors	1. Gas mask 2. Hose mask with blower 3. Self-contained oxygen breathing apparatus	The gas mask for protection against the particular contaminant encountered would probably be the first choice. Oxygen breathing apparatus probably would be last choice, because of weight and training requirements.
Low concentration of toxic gases and vapors (moderately above toxicity or irritating range).	1. Gas masks 2. Chemical cartridge respirators 3. Air-line respirators	Hose masks and oxygen breathing apparatus would be applicable, but probably not practical.
Pneumoconiosis-producing and nuisance dusts (asbestos, silica, cement, coal, etc)	1. Type A: Pneumoconiosis producing and nuisance dust respirators	Air-line respirators would be selected if dust concentration is very high. However, filter respirators would be satisfactory if air-line equipment interferred with operation.
Toxic dusts (lead, cadmium, manganese, selenium, etc.)	1. Air-line respirators 2. Toxic dust respirators 3. All-dust respirators	Choice will depend upon working conditions and materials causing exposure. Knowledge of concentrations of contaminant in working room might be determining factor in selection
Fume (from burning of lead, cadmium, etc.)	1. Type B fume respirators 2. Air-line respirators	Fume is very small particulate matter and ordinary filter respirators will not afford protection. Final choice will probably depend on working conditions.
Gases and particulate matter	1. Gas masks with suitable filter 2. Cartridge-type respirator with suitable filter. 3. Air-line respirator	Frequently protection must be afforded against a combination of gases and particulate matter. Final choice will depend upon working conditions, freedom of movement, and whether gas mask or cartridge respirators will give adequate protection against gases present.

TABLE I

ATOMOSPHERIC CONTAMINANTS TO BE PROTECTED AGAINST:	COLORS ASSIGNED
Acid gases	White
Hydrocyanic acid gas	White with ½ inch green stripe completely around the canister near the bottom
Chlorine gas	White with ½ inch yellow stripe completely around the canister near the bottom
Organic vapors	Black
Ammonia gas	Green
Acid gases and ammonia gas	Green with ½ inch white stripe completely around the canister near the bottom
Carbon monoxide	Blue
Acid gases and organic vapors	Yellow
Hydrocyanic acid gas and chloropicrin vapor	Yellow with ½ inch blue stripe completely around the canister near the bottom
Acid gases, organic vapors, and ammonia gases	Brown
Radioactive materials, excepting tritium and noble gases	Purple (Magenta)
Particulates (dusts, fumes, mists, fogs, or smokes) in combination with any of the above gases or vapors	Canister color for contaminant as designated above, with ½ inch gray stripe completely around the canister near the top
All of the above atmospheric contaminants	Red with ½ inch gray stripe completely around the canister near the top

TECHNICAL BULLETIN

BERYLLIUM

PROPERTIES

Elemental beryllium is a greyish, brittle, metal having many unusual properties. Some of the physical properties of beryllium and several of its commercially important compounds are:

	beryllium	beryllium oxide	beryllium fluoride
Atomic Weight	9.01	25.01	47.01
Specific Gravity (g/cc)	1.85	3.01	1.986
Melting Point	1278	2530 ± 30	800
Boiling Point	2970	3900	

The main commercial source of beryllium is from the ore, beryl, which is beryllium aluminum silicate. Prior to 1950, beryllium was used mainly for the production of beryllium-containing alloys such as beryllium coppers and beryllium nickel. It was an ingredient in phosphors used in fluorescent lamps; early beryllium poisoning cases from this industry are well documented. Beryllium is now used extensively in the nuclear and aerospace industries.

HEALTH HAZARDS

The OSHA 8-hour time weighted average allowable limit for beryllium and beryllium compounds is 0.002 milligrams per cubic meter of air (mg/m^3). OSHA has also established a ceiling limit for beryllium of 0.005 mg/M^3 and an acceptable maximum peak above the acceptable ceiling concentration of 0.025 mg/M^3 for a maximum duration of 30 minutes.

Beryllium and its compounds are among the most toxic of the metals used by industry. Inhalation of the dust or fume can result in chronic or acute beryllium poisoning depending upon the length of exposure and the concentrations involved.

Acute poisoning takes the form of an acute pneumonitis while the chronic form of berylliosis is manifested by a variety of pulmonary symptoms including dyspenea and cough. (It is considered by some a systemic illness.) Chronic berylliosis often results in permanent disability or death. There is often a period of several years between the last beryllium exposure and development of the disease.

Beryllium fluorides will, and other soluble compounds may, cause dermatitis and irritation of the nose, throat and eye. Ulcerations may result from embedded particles in the skin.

FIRE HAZARDS

In the finely divided powder form, beryllium metal constitutes a potentially serious fire hazard. Beryllium in the solid form and most compounds of beryllium do not present a fire hazard.

FIRST AID

In acute inhalation exposures, remove worker from further exposure and call a physician at once. Any worker suffering either a cut or abrasion must report for first aid immediately.

MEDICAL PROCEDURES

1. Preplacement Examinations: Prior to any beryllium exposure, workers should have a complete physical examination including routine blood, urine, serology, full size chest x-ray and vital capacity test. Persons showing any of the following should be excluded from beryllium exposure:

   a. Previous or existing respiratory diseases such as asthma, hay fever or bronchiectasis.

   b. History or signs of chronic disease of the liver or kidney.

   c. History of heart disease.

   d. Vital capacity depression of more than 10 percent below the normal calculated for the individual.

2. Periodic Examinations: Workers with a beryllium exposure should have the following:

   a. Semi-annual chest x-rays and routine blood and urine analysis

   b. Annual standard physical examinations.

3. If accidental acute exposure occurs, chest x-rays should be made within a week. Lung changes do not usually occur within three weeks of such an exposure, so that an early x-ray is necessary for use as a baseline record.

HEALTH HAZARD CONTROL METHODS

1. Local exhaust ventilation must be furnished at all locations where beryllium dust, fume or mist could be released. It usually is necessary to enclose machining, grinding, melting,

cutting, and similar operations and provide exhaust ventilation for these enclosures. General room ventilation is not satisfactory to control dust, mist, or fume.

2. All exhaust systems should be provided with an appropriate air-cleaning device to collect beryllium. The handling of the collected waste should be carefully devised to minimize worker exposure.

3. The collection and analysis of air samples to evaluate employee exposures to beryllium is the only satisfactory method of determining effectiveness of engineering controls. Air samples should be collected on a routine basis and as soon as possible after the modification or installation of processes.

4. Good housekeeping must be maintained in areas where beryllium is handled and used. Dry sweeping, brushing and cleaning with pressurized air should be prohibited. Exhaust from vacuum cleaners should be connected to a beryllium exhaust system. Portable vacuum cleaning equipment must be supplied with absolute type of filters. Wipe samples should be made periodically to monitor effectiveness of housekeeping.

5. Workers should be provided with washable clothing (Preferably synthetic to reduce dust retention) such as coveralls, or shirts and trousers. Work clothing must not be worn or carried home by workers.

6. Laundering of work clothing of beryllium workers should either be done in the plant or by a commercial laundry set up to handle clothing contaminated with toxic materials.

7. Adequate change, washing and shower facilities must be provided. Workers should shower and change to clean street clothing before leaving the plant.

8. Visitors should be kept at a minimum in areas where beryllium is used.

9. Respiratory protection, if necessary for emergencies or unavoidable exposures, should be of the supplied-air type, or of the type approved by NIOSH/MESA Approved for dusts, fumes and mists having a time-weighted average less than 0.05 Mg/M^3.